The practice of feeding rumen inert fats as added ingredients to dairy rations of high yielding cows started in the early ‘80s as a way of increasing dietary energy levels. Since then there has been significant research and product development to find optimum ways of delivering fatty acids to the dairy cow. There is now a large international business amounting to over 1.5 million metric tons sold per annum of specialty fat products aimed at the dairy cow.

Worldwide demand for dairy products is increasing exponentially. Cow milk yields are increasing. Our understanding of dairy cow nutrition is improving, and cow genetics are improving too. There is growing demand for fat products for inclusion in dairy rations, but there are a number of factors that are changing the world supply of fats and oils which include more requirement for human nutrition purposes, increased oleo-chemical manufacturing and demand for renewable energy sources through biodiesel. This demand is offset by major challenges to the world supply.

Palm oil is the largest source of edible oil followed by soy oil. Respectively they account for 32% and 24% or 56% combined of all edible oils and fats. Malaysia used to be the largest single producer of palm oil but has been recently surpassed by Indonesia. Palm oil is a major raw material for biodiesel production. The majority of fat that is fed to dairy cows worldwide is of palm origin except in the US where tallow is a major raw material source. Both Malaysia and Indonesia are facing a number of problems with regard to their palm oil production which will likely have a major impact on availability and pricing in the future. These include static to declining yields, particularly in Malaysia, fierce lobbying to prevent more deforestation, climate change and serious quality issues of the oils caused by adulteration and contamination.

Further research on fats and oils in animal nutrition is demonstrating that individual fatty acids have significantly different metabolic roles to play, and this will likely have an effect on demand for different fatty acid streams.

Overall it is concluded that fats and oils availability will go through major changes in the years ahead. Renewable fuel policies across the globe are most likely to be the most significant factor driving price changes. The edible applications of fats and oils will grow, and this will particularly drive demand in emerging economies as standards of living increase. Industrial applications will continue to grow.

The impact of global climate change is likely to have a detrimental impact on plants producing fats and oils as the primary geographies producing these might be the most vulnerable.

**Trevor Tomkins** has worked for his entire career in the world-wide dairy industry. He completed his B.S. Hons in Agriculture and then Ph.D. in Animal Production at the University of Reading, UK in 1974. He joined the multi-national Dutch Company Wessanen B.V. and lived and worked in South Africa and traveled extensively as International Technical Advisor. In 1979 he
joined Volac in the UK and was part of the team that first commercialized calcium salts of fatty acids. In 1985 he joined Milk Specialties Global as Vice President of Research and Technical Services and with his family immigrated to the United States. In 1996 he became President of Milk Specialties Global and oversaw the growth of the company to become one of the largest independent specialty animal nutrition and human nutrition milk and fat processing companies in the US. He retired from Milk Specialties in 2012 and founded venture|dairy to bring modern technology, access to capital and access to formal markets for small farmers in emerging economies. For the last seven years he has worked extensively in East Africa and India. He has been a member of the Malaysian Palm Oil Board Program Advisory Committee for the past twelve years.

Wednesday May 29, 2019

Kickoff Speaker: Lipid Functions in Dairy Cattle – From Energy to Metabolic Modifiers
Kevin Harvatine, The Pennsylvania State University

Traditionally, dietary fat was used to increase dietary energy density without increasing diet fermentability, but the broad impacts of fat on rumen fermentation and as a bioactive nutrient continues to evolve our understanding of the impact on the cow. The talk will overview our understanding of the important aspects of dietary fat and attempt to set the stage for the subsequent in-dept talks and discussion.

Important aspects of dietary fats are their effect on rumen fermentation, fatty acid digestibility, dry matter intake, energy balance, and milk and milk fat production and their ability to modify physiological processes such as reproduction and immunity. Fatty acids are nutritionally the most important aspect, but feed FA profile is extensively modified by rumen microbial metabolism making prediction of absorbed FA profile difficult. Digestibility of fat supplements is variable in the literature and has recently become of key interest. The impact of fat on feed intake was well investigated through abomasal infusion and meta-analysis approaches and generally feeding unsaturated and calcium salts are associated with decreased feed intake. Biohydrogenation induced milk fat depression is arguably one of the best examples of a bioactive nutrient with a major impact on animal physiology. Effect of other fatty acids on reproduction, health, and nutrient partitioning are more difficult to experimentally identify, but of key importance.

Animal performance is the result of many interacting factors. It is difficult to consider complex interactions in experimental research, but these interactions are key to field application. Traditionally, nutrition research and nutritionists have asked the binary yes/no question, does X, Y, or Z work? In fact, the question is much more complex and depends on many interacting factors. We really need to ask, when does product X, Y, and Z work? One key interaction is cow level of production, which as an impact on rumen dynamics and nutrient partitioning. We will discuss how we might be mindful of these interactions as we discuss the impact of fat on the dairy cow.

Our knowledge of nutrition is guided by diverse information that range from field observations to mechanistic experiments and meta-analyses. The diverse background and
experience of the Discover Conference audience provides an awesome opportunity to integrate these sources to recognize what we know well, discuss what we don’t know well, and identify key gaps and how we can fill them.

**Kevin J. Harvatine** is an Associate Professor of Nutritional Physiology at Penn State University. He grew up on a dairy farm in Pennsylvania and received his BS in Animal Science from Penn State. His conducted his MS work at Michigan State University working with Dr. Mike Allen and PhD and postdoc work at Cornell University working with Dr. Dale Bauman and Dr. Yves Boisclair. His area of expertise is nutritional regulation of metabolism. Currently he investigates regulation of milk fat synthesis, omega-3 fatty acid metabolism, and circadian regulation of lactation. His lab conducts experiments ranging from applied dairy nutrition to mechanistic molecular biology experiments.

**The Basic Language of Lipids**
*James Drackley, University of Illinois*

**Jim Drackley** is Professor of Animal Sciences at the University of Illinois at Urbana-Champaign. Dr. Drackley grew up on a small dairy farm in southwestern Minnesota and received his B.S. in Dairy Production (1981) and his M.S. in Dairy Science (1985) from South Dakota State University. Dr. Drackley joined the faculty of the University of Illinois in 1989 after receiving his Ph.D. in Nutritional Physiology (1989) from Iowa State University. Drackley’s research program centers on dry period nutrition and metabolism of transition cows, metabolism in the liver of ruminant animals, lipid utilization and metabolism in ruminants, and aspects of calf nutrition and management. He has been awarded over $4.4 million in research funding as principal investigator since 2006. Drackley has edited 2 books and authored or co-authored 1 book, 12 book chapters, 176 scientific articles in refereed journals, and over 400 abstracts, technical reports, articles in conference proceedings, and popular press articles. He has trained 40 graduate students and is consistently on the “List of Excellent Teachers” as voted by the students at the University of Illinois. Dr. Drackley has presented seminars and lectures on dairy nutrition in 30 US states, 10 Canadian provinces, and 24 other countries. Dr. Drackley has received numerous awards for his research and teaching, including the Paul A. Funk Recognition Award from the College of ACES in 2008, and the 2002 American Feed Industry Award for Excellence in Dairy Cattle Nutrition Research and the 2007 Nutrition Professionals, Inc. Applied Dairy Nutrition Award from the American Dairy Science Association (ADSA). Drackley was named a Fellow of ADSA in 2015. Drackley has served on the Board of Directors for ADSA, as President of the Midwest Branch of ADSA, and Chair of the Production Division of ADSA. Dr. Drackley also has worked extensively with dairy and feed industry groups around the world, and Currently, he is a member of the National Research Council committee to produce the 8th edition of the NRC publication “Nutrient Requirements of Dairy Cattle”. Drackley resides in Urbana, IL.

**Analysis of Fats – Present and Future**
*Ralph Ward, Cumberland Valley Analytics Services, Inc.*

**Ralph Ward** is the founder and owner of Cumberland Valley Analytical Services (CVAS), a key laboratory providing forage and feed evaluation services in the U.S. and globally for the past 25
years. With a background in dairy production and nutritional services, Mr. Ward has focused on the development of analysis systems for forage quality determination and modeling in dairy rations. His current focus is improving starch digestibility methods, modeling of NDF digestibility, developing systems to understand forage and feed fragility and expanding an international network of forage evaluation laboratories.

Factors that Modify Differences in Rumen Fatty Acid Outflow Versus Feed Input
Tom Jenkins, Clemson University

The fatty acids consumed by dairy cows are extensively transformed into a vast array of unique isomers by the microbial population in the rumen. The transformation process can limit the supply of unsaturated fatty acids needed by body tissues for optimization of essential functions like reproduction and immunity. Most important to the dairy producer is that some intermediates of the transformation process generate lipid compounds that can alter the composition of milk, including causing a reduction in milk fat content. This can lead to considerable revenue loss and profitability for the dairy producer making the control of these rumen lipid compounds a research priority. Recent results from fat feeding and rumen microbiology studies have suggested a sequence of events that occur in the rumen that promotes accumulation of the undesirable intermediates that reduce milk fat. The chain of events is initiated at the time of feeding with a sharp increase in fatty acid concentration in ruminal contents soon after or concurrent with eating. Because high concentrations of unsaturated fatty acids have antibacterial activity, negative effects on growth and metabolism occur for some species of ruminal microorganisms. The antibacterial effects are aggravated by high starch in the diet, either due to a rise in lactate concentration or a lowering of rumen pH. A shift in the fatty acid transformation process then follows the antibacterial insult leading to a gradual buildup of undesirable fatty acid intermediates. Buildup of the undesirable intermediates continue with each successive feeding of the same diet followed by a steady decline in milk fat content. Several practical feeding guidelines can limit antimicrobial effects and help to maintain or regain milk fat. These include, but are not limited to, restricting the amount of unsaturated fat fed to cows, slowing the release of fatty acids in the rumen such as is seen with feeding whole cottonseed, feeding more frequently to lower the peak fatty acid concentration, and managing starch and rumen pH within acceptable ranges.

Tom Jenkins attended Penn State University for his BS and MS degrees, and received a Ph.D. at Cornell University. After a postdoc at The Ohio State University, he then moved to Clemson University where he continued work on dairy cattle nutrition for over 30 years teaching courses in nutrition and coordinating research on fat feeding and rumen lipid metabolism. Since Dr. Jenkins’ retirement from Clemson University in 2012 he has remained active consulting in dairy nutrition for a number of clients. He has published extensively in scientific journals and conference proceedings and has given numerous invited presentations across more than a dozen countries on lipid metabolism in dairy cattle and the practical aspects of fat feeding. Dr. Jenkins has received numerous awards from Clemson University and The American Dairy Association for his research accomplishments in rumen lipid metabolism.
The Five Fatty Acids We Feed Cows: Their Positive and Negative Effects on Secretion of Different Milk Fatty Acids
Lou Armentano, University of Wisconsin, Madison

This presentation reviews a wide group of studies where lactating cows were fed basal diets relatively low in fat, along with diets that increased the fat content using concentrated sources of fat so that the dietary change was mostly the addition of fat. Our focus was the effect fat content in the cow’s diet on the yield and composition of fat in the milk. Total milk fat concentration is widely measured and used to determine milk value, were more far means a higher price for the milk. Milk fatty acid composition is not routinely measured, nut new technologies make this easier to measure in a commercial setting than it was before.

If we considered the sum of all dietary fat on the yield of total milk fat, then we were not able to predict any trend in total milk fat produced. However, if we distinguished the dietary fat into its main fatty acid components, which varied across studies, we did find relationships. The dietary fatty acids include two saturated fatty acids (palmitate with 16 carbons and stearate with 18 carbons) and three unsaturated fatty acids all with 18 carbons (oleate, linoleate and linolenate). It was also important to look carefully at the fatty acids that made up the milk fat produced. Unlike the cow’s diet which is pretty well described by the five major fatty acids listed above, milk fat has 400 or more different fatty acids, with about 15 making up most of the mass of milk fat yield. These can be broken up into three groups: the shorter chain saturated fatty acids with less than 16 carbons that are made by the cells in the cow’s mammary gland; the 18 carbon fatty acids, primarily oleate and some stearate, derived from the diet or body fat tissues via the mammary blood supply; and palmitate, a 16 carbon saturated fat which can be derived from diet, fat tissues, or made in the mammary gland. So, by studying the five major dietary fatty acids as separate inputs, and the three major groups of milk fatty acids (<C16, C16 and C18) as outputs, we were able to find some very clear relationships. When fatty acids are fed in the diet, they are always transferred into milk fat, albeit with varying efficiency. This means if we feed any of the four dietary C18 fatty acids, we see more C18 fatty acid (mostly oleate and stearate) yield by the cow in her milk. If we feed more C16, then we see more C16 yield in the milk. At the same time, if we feed unsaturated fatty acids, the synthesis of C16 and shorter fatty acids in the mammary gland decreases, so this part of the milk fat yield is lowered and offsets the increase in longer chain milk fatty acids. Linoleate was more potent at doing this than oleate or linolenate, but all three dietary unsaturated fatty acids had this effect.

What this means is that when adding fat to the cow’s diet, total milk fat yield may not have changed enough to notice, but the composition of the milk fat changed from short, saturated fatty acids, to 16 and 18 carbon fatty acids. This is important because total fat is what is normally measured at the farm and is the basis for payment. However, fatty acid composition of milk can change manufacturing and organoleptic properties, such as melting point and mouth feel. Also, these changes in milk fatty acids can alter human lipoprotein biomarkers and the proportion of milk fat that contributes to the saturated and trans fatty acid part of the food label. Also, milk fat total yield can be increased by limiting the most negative dietary fatty acid, which is linoleate, provided that adequate linoleate is provided to maintain cow health and reproductive function.
Louis Armentano graduated from Cornell University in 1975, earning a B.S. with distinction in Animal Science. He went to North Carolina State to study the use of by-products as feeds for dairy cattle and received an M.S. in Animal Nutrition. His Ph.D. was from Iowa State where the relationship between rumen carbohydrate fermentation and the metabolic processes of cattle was examined at the whole animal level. After a brief research appointment at Virginia Tech working with protein nutrition of dairy cows, Lou joined the Department of Dairy Science at Madison in 1983 as an Assistant Professor with teaching and research responsibilities. In addition to a program studying basic liver metabolism in cattle, Lou has maintained a program addressing use of by-product feedstuffs and their role in providing energy, fiber, and protein to dairy cows. His most recent research efforts have been to explain the effects of dietary fat on milk fat secretion and resulted from examining the effects of the sometimes-high levels of corn oil found in distillers grains. In addition to serving as a professor for 33 years at the University of Wisconsin-Madison, Lou had the pleasure of chairing the department for 8 busy and exciting years. In 2016 Lou moved his appointment from Full Professor to Professor Emeritus but is still involved in dairy research and outreach. He currently serves on the National Research Council dairy nutrition guidelines writing committee and holds the office of past-president in the American Dairy Science Association and President of FASS.

Fatty Acid Variation in Feeds: Embracing Variation and Recognizing the Potential Impact on Dairy Cattle Health & Performance
John Goeser, Rock River Laboratory, Inc.

Historically, decisions in the fatty acid nutrition space have centered on using ether extract data for diet components in practical situations. Reason being, more advanced fatty acid profile analyses were both time consuming and expensive. More recently, fatty acid chemistry and near-infrared reflectance (NIR) predictive models have advanced such that routine measures of both total fatty acid (TFA) and fatty acid (FAP) profile of farm grown feeds and total mixed rations (TMR) are possible. The National Research Council (2001) committee estimated that TFA could be derived by assuming TFA = EE - 1, extrapolating from TFA data published relative to EE to that point. TFA is understood to be less than EE, however the real difference in means is less clear. Recent (unpublished) observations suggest that TFA techniques and data interpretation (i.e. peak misidentification when integrating area under curves during FAP chromatogram analysis) may not be uniform between laboratories. This point warrants further discussion and exploration.

Using NIR predictive models derived from chemistry performed by Professor Lock’s Lab, Michigan State University, suggest that mean ether extract and TFA differ by 0.5, 0.5, 1.5, 1.4, and 1.1 units (DM basis) for corn grain, hay, small grain silage, haylage, and corn silage, respectively. The distributions in TFA are similar or less than EE for all feeds discussed here.

To interpret what impact this may have on practical nutrition consider the following situation. Rumen unsaturated fatty acid load (RUFAL) has become a commonly understood nutrition metric nutritionists consider in formulating diets to avoid milk fat depression. Incorporating the data discussed here, alongside NIR predicted FAP, to calculate true RUFAL and then comparing to a RUFAL estimated from using EE values for feeds suggests that there may be up to 1% unit range in true TMR RUFAL (DM basis) for at an exemplary 2% TMR
RUFAL (using from EE values). At 25 kg intake, 1% TMR DM RUFAL range equates to a 250 g potential error in RUFAL estimation. This variance may prove costly for commercial dairy farms. However, with advances in analytic technology and NIR models, fatty acid nutrition can and should continue to evolve. Similar to how amino acid nutrition has evolved, nutritionists in the future will be able to better formulate with specific fatty acid supply and requirements in mind.

John Goeser grew up in the dairy industry as his family’s dairy near Plymouth, Wisconsin grew from 60 head in the 1980’s to now over 1,000 cows. Goeser holds several degrees from the University of Wisconsin – Madison, including B.S. degrees in Dairy Science and Agronomy; M.S. degrees in Plant Breeding & Genetics and Dairy Science; and a Ph.D. in Dairy Science. Goeser has offered dairy nutrition and management expertise for over 10 years and has been with Rock River Laboratory since 2012. In 2014, Goeser joined the UW-Madison Dairy Science department as an adjunct professor and also began consulting for agricultural businesses as a side venture. With Rock River Laboratory, Goeser oversees animal nutrition, technical support and research. Goeser’s focus with Rock River laboratory is improving our understanding of carbohydrate digestion, forage management, and feed hygiene.

Important Considerations for Lipid Models

Joanne Knapp, Provimi NA

Significant advances have been made over the past 20 years in understanding the microbial metabolism of dietary lipids, intestinal digestibility of fatty acids, post-absorptive tissue utilization, and regulation of milkfat synthesis. Many of these advances have been adapted into ration balancing models, including the landmark work of Moate et al. (2004) that established a mathematical model of hydrolysis, biohydrogenation, and intestinal availability of fatty acids. Combined with advances in analytical capability to measure individual fatty acids in feed ingredients, these improvements have allowed us to augment existing dairy nutrition models and be able to evaluate the potential impacts of biohydrogenation on milkfat synthesis and the intestinal proportions of Ω3 and Ω6 fatty acids on reproduction. Additional areas that could further enhance lipid sub-models in ration balancing software would include interactions between individual fatty acids and also between lipids and other dietary fractions, e.g. carbohydrates, on fatty acid digestibility and absorption, enhanced prediction of bioactive fatty acids that impact milkfat synthesis, and quantitative estimates of tissue utilization of fatty acids during different stages of lactation. These enhancements would allow better prediction of animal responses to dietary changes and fat supplementation.

Joanne Knapp is the Dairy Innovation Leader for Provimi U.S. and an adjunct professor in Animal Sciences at The Ohio State University. She guides a 15-person team in providing technical support in dairy nutrition and management to Provimi customers and developing new products, services, and solutions through collaboration with colleagues across the Cargill organization. Joanne attended Cornell University, graduating with a B.S. with Honors in Animal Science, and earned her M.S. and Ph.D. degrees in Nutrition at the University of California-
Davis. She has more than 30 years of experience in agriculture, animal and human nutrition, and statistics and biomathematics from previous positions as a professor in Animal Science at the University of Vermont, as Director of Nutrition for the San Joaquin Valley operation of J.D. Heiskell & Co., and as the President and Principal Consultant at Fox Hollow Consulting LLC. Joanne is a well-recognized expert in metabolic regulation and mathematical modelling of biological systems ranging from tissues to farm systems. Joanne is active in professional organizations, where she has served as a committee member and officer for ADSA and ARPAS and an ad hoc reviewer for several journals and USDA grant panels. Joanne is also a passionate advocate for the role and sustainability of animal agriculture in the global food supply.

Thursday May 30, 2019

**Review of Meta-Analysis for Fatty Acid Digestibility**  
*Jackie Boerman, Purdue University*

Ruminants consume mostly unsaturated esterified fat (i.e. triglycerides or glycolipids), the rumen modifies these fats through hydrolysis and hydrogenation and the fat leaving the rumen contains more saturated fatty acids (FA). While monogastrics utilize monoglycerides as an amphiphile to aid in the transfer of FA from the lumen to the enterocyte, due to little esterified fat reaching the small intestine, ruminants rely on lysolecithin to act as an amphiphile and improve FA digestibility. In most dairy diets, due to the changes that occur in the rumen, the most abundant FA reaching the duodenum is stearic acid (C18:0). Differences in individual FA abundance reaching the small intestine influences FA digestibility.

Meta-analyses utilizing data from both individual cows and study means reported increases in duodenal flow of FA as FA intake increased. As duodenal flow increased, total FA digestibility is reduced with not all FA responding the same. Unsaturated 18-carbon FA (C18:1, C18:2 and C18:3) showed no differences in digestibility across the range of duodenal flow reported. However, as levels of C18:0 reaching the duodenum increase, digestibility of C18:0 is reduced. The reduction in total FA digestibility is primarily from the reduction in C18:0 digestibility as more FA reaches the small intestine. Individual studies that dosed increasing amounts of saturated FA showed a more negative effect on FA digestibility when dosing C18:0 than C16:0.

Utilizing meta-regression to determine which factors impact individual FA digestibility, the concentration of other FA impact digestibility. For example, C18:2 digestibility is negatively impacted by the concentration of C18:0 that reaches the duodenum. Indicating that profile of FA and not just the amount of FA reaching the duodenum impacts digestibility. An individual dosing study where C16:0 was supplemented in a low-fat diet reported reduced total FA digestibility compared to C16:0 supplemented in a higher fat diet. Therefore, the profile that reaches the duodenum in addition to the amount of individual FA likely influences digestibility. Due to differences in digestibility, the amount of digestible energy available to the cow differs based on fatty acid flow and profile. These changes in digestible energy between individual FA influences production responses observed when supplementing fat.
In order to accurately predict digestibility of FA and digestible energy from FA, we need to not only treat individual FA as unique when it comes to predicting their digestibility but also consider their interactions with other FA and their effect on digestibility of other nutrients. Cows consume blends of FA and because of the difficulty in predicting biohydrogenation and passage rates of FA, accuracy of individual FA reaching the duodenum will be challenging. However, a first step is accounting for differences in digestibility as flow increases and not treating all FA as having the same digestibility and digestible energy.

Jackie Boerman is an assistant professor in the Department of Animal Sciences at Purdue University. She grew up on a dairy farm in western New York and received her BS from Cornell University. Jackie received her MS from the University of Illinois and her PhD from Michigan State University. In 2017, Dr. Boerman began an extension/applied research and teaching appointment at Purdue University after working for 2 ½ years in industry. Her research and extension programs are focused on nutrition and management strategies that promote the production and health of dairy cattle. Currently she is interested in understanding tissue mobilization around calving and how to best utilize data that is generated on farms to aid in decision making.

Opportunities to Improve Fatty Acid Digestibility
Adam Lock, Crystal Prom and Jonas de Souza, Michigan State University

Fatty acid (FA) absorption impacts directly on energy intake and the efficiency of nutrient use and can be affected by several factors including the total amount and profile of FA reaching the duodenum and limitations in emulsification capacity. Before FA absorption can occur, it is necessary for the lipid material absorbed onto the feed particles to be solubilized into the aqueous environment. Lysolecithin together with bile salts desorb FA from feed particles and bacteria, allowing the formation of micelles. In ruminants, micelle formation is the key to this process and, therefore, key to efficient FA absorption. Once micelles are formed, they facilitate transfer of water-insoluble FA across the unstirred water layer of intestinal epithelial cells, where the FA and lysolecithin are absorbed. Amphiphilic compounds, such as lysolecithin, have the ability to expand micelle size and the hydrophobic interior, which allows greater incorporation of FA into the micelle.

In general, as rumen outflow of FA increases the absorption of FA in the intestine is reduced. Recent research has highlighted differences in intestinal digestibility among palmitic (C16:0), stearic (C18:0), and oleic (C18:1) acids, which impacts the amount and profile of absorbed FA available for metabolic purposes including milk fat synthesis. Our results suggest that a combination of 16-carbon and unsaturated 18-carbon FA may improve FA digestibility. When comparing combinations of C16:0, C18:0, and C18:1 in supplemental fat we observed that FA digestibility increased when a supplement containing more C18:1 was fed compared with a control diet. Also, FA digestibility was markedly reduced when a supplement containing more C18:0 was fed compared with the other FA treatments due to decreases in both 16- and 18-carbon FA digestibility. Recently, we observed that increasing C18:1 and decreasing C18:0 in a supplemental fat blend increased FA digestibility. These results are likely due to increased flow of
C18:1 to the small intestine since we also observed that abomasal infusion of C18:1 improved FA digestibility.

Unfortunately, there is a paucity of reports that have attempted to overcome potential limitations in emulsification capacity in the intestine. If we can improve FA absorption while increasing FA intake, we should be able to improve the utilization of nutrients, feed efficiency, and milk production. We recently observed that an exogenous emulsifier offers the potential to improve FA absorption and milk production. Recent results with different exogenous emulsifiers and site of infusion will be presented. Overall, these findings suggest that emulsification in the small intestine may be a limiting step to digestion of FA, especially as FA intake and flow increases.

In the future, the opportunity and challenge will be to continue to improve our understanding of how and which FA affect nutrient digestion, energy partitioning, and milk synthesis and effectively applying this knowledge in the feeding and management of high producing dairy cows.

Adam Lock is an associate professor in the Department of Animal Science at Michigan State University. Originally from a dairy farm in the southwest of the United Kingdom, Dr. Lock received his PhD from the University of Nottingham and completed a post-doc at that institution as well as at Cornell University. He had a research and teaching appointment at the University of Vermont from 2006 to 2009 before moving to his current research and extension appointment at Michigan State University in the fall of 2009. His research and extension programs focus on fatty acid digestion and metabolism in the dairy cow and the impact of bioactive fatty acids on animal production and human health.

What is the Economic Value of Supplemental Fats? It Depends
Bill Weiss and Maurice Eastridge, The Ohio State University

Supplemental fat sources are not essential for dairy cows; therefore, their inclusion into diets should be a purely economic decision. If the total return when fat is added to the diet does not exceed the marginal change in feed cost, fat should not be fed. Under most situations, energy (NEL) from starch is substantially less expensive than NEL from fat supplements. Based on economics, diet energy should first be increased by replacing fiber with starch until starch concentrations cannot be increased further because of animal health issues or milk fat depression. At that point, the marginal value of NEL from fat is greater than that of starch, and the economic value of fat should be calculated based on expected animal responses. Some of these responses are easy to quantify, while others are not. Based on a meta-analysis, on average, supplemental fat reduces DM intake and increases yields of milk and milk fat. Depending on feed costs and the price of milk and milk components, the value of a fat supplement ranges from break-even (i.e., no economic value to including) to returning more than twice its cost. In addition to feed cost and milk prices, the type of fat supplement, the nutrient being replaced when fat is fed, stage of lactation, cow grouping system, and production level of the pen or herd all affect the economic value of fat. The gross return based on expected change in DMI and milk component yields can vary by about 2-fold between common supplements. Because of different prices for supplements, the net return would vary less but still could be substantial. The basal diet affects economic value
of fat supplements. Fat had minimal economic value when replacing soyhulls in a diet that contained whole cottonseed but had substantial value in diets without whole cottonseed. Limited data indicate that the milk yield response to fat increases as milk yield of the cow increases and is higher for cows during peak milk periods versus for fresh cows. Depending on the production level of the herd, feeding a single diet to all cows could reduce and may even eliminate the economic benefits of feeding fat. Therefore, the economic value of fat could increase if cows are grouped by production and dietary fat is targeted appropriately.

If dietary fat only affected milk component yields and DMI, defining the economic value of fat would be straightforward; however, fat supplements can affect changes in body condition, animal health, and reproductive efficiency. Putting an economic value on these responses is much more difficult. In one study, feeding supplemental fat based on changes in DMI and milk component yields, supplemental fat was worth approximately $4.90/kg; however, the cows on that treatment lost 24 kg of body weight, which could affect reproduction or later lactation milk yields. Although difficult to economically value, such responses must be considered when making decisions regarding fat supplementation. Definitive data on effects of fat on reproduction are limited; however, a meta-analysis suggested that fat may increase pregnancy rate by 20%. Depending on the reproductive efficiency of the herd, that improvement could be worth from $0.4 to 1.5/kg of supplemental fat fed. However, the value for reproduction may be $0 (lack of statistical significance). In conclusion, numerous factors must be considered when determining the economic value of fat supplementation.

**Bill Weiss** is a Professor of Dairy Cattle Nutrition in the Department of Animal Sciences at The Ohio State University located at the Ohio Agricultural Research and Development Center in Wooster. He earned degrees from Purdue University and Ohio State. He has been on the faculty of Ohio State since 1988 with a joint research/extension appointment. His main research areas are: 1) incorporating variation in cow and diet factors into ration formulation; 2) factors affecting digestibility in dairy cows and methods to estimate diet energy; and 3) relationships between minerals and vitamins and health of dairy cows. He has authored more than 500 journal and popular press articles and is a frequent speaker at national and international conferences. He was a member of the 2001 Dairy National Research Council (NRC) committee and is currently serving as vice chair of the 2018 Dairy NRC committee. From 2016-2018 he served as interim chair of the Department of Animal Sciences.

**Maurice Eastridge**, Professor and Extension Dairy Specialist, has been on the faculty in the Department of Animal Sciences at The Ohio State University since March 1986. His responsibilities include teaching, Extension, and research in dairy cattle nutrition and management. He received his MS and PhD from Purdue University. At the university and college levels, he has been recognized for his outstanding service to students and student development, and he has received several awards for his Extension and research programs, including the Delaval Dairy Extension Award and the Applied Dairy Nutrition Award from the American Dairy Science Association. He chairs the Board of Directors for the Tri-State Dairy Nutrition Conference ([http://tristatedairy.org](http://tristatedairy.org)), serves as Chair of Board of Directors for the North American Intercollegiate Dairy Challenge, and is editor of the bi-monthly publication, Buckeye Dairy News ([http://dairy.osu.edu](http://dairy.osu.edu)). He was appointed as Associate Chair, Department of Animal Sciences at Ohio State in June 2018.
Essential Fatty Acids: Evidence of Deficiencies
Rachel Gervais, Laval University

Similar to other animals, the cow cannot synthesize both linoleic acid (18:2 n-6) and linolenic acid (18:3 n-3) from stearic acid (18:0) due to absence of Δ-12 and Δ-15 desaturases. Therefore, these fatty acids (FA) are considered essential and must be provided in the diet in order to support normal physiological function and animal health. Furthermore, the potential beneficial effects of n-3 FA on consumer health have motivated the study of strategies to increase these FA in ruminant-derived products. Through sequential desaturation and elongation reactions, cows convert with, with varying efficiencies, 18:2 n-6 and 18:3 n-3 into long chain polyunsaturated FA with important physiological roles (e.g. 20:4 n-6, 20:5 n-3 and 22:6 n-3). Several decades of in vivo and in vitro research have provided insight into the transformations FA undergo before they are available to the ruminant animal. However, prediction of available FA is difficult, as many factors can affect it, namely level of feed intake, rates of ruminal lipolysis and biohydrogenation, and intestinal absorption. Furthermore, predicting uptake and effects of essential FA at the tissue level can prove equally challenging. To help protection of unsaturated FA from rumen biohydrogenation and thus increase their duodenal supply, numerous technologies have been developed with varying degrees of success, and novel emerging technologies are currently being explored. Despite the essential nature of n-3 and n-6 FA, the possibility of negative effects, through increased production of lipid peroxidation products, could potentially result in diminished cow health and milk quality. Before blunt and blind advice to increase dietary supply of essential FA is given, future research efforts must focus on weighing the benefits and drawbacks of such dietary interventions.

Rachel Gervais completed her bachelor’s and PhD studies in animal sciences at Université Laval. She completed her postdoctoral studies at Ghent University in Belgium. She is now a professor in the Department of Animal Sciences at Université Laval. Dr. Gervais’ research focuses on the effects of diet and nutrition on milk composition, vitamin B supply and enteric methane emissions in dairy cows, mechanisms at work in dairy cows for the synthesis and secretion of fatty acids in milk, and the possibility of using fatty acids in milk as a diagnostic tool.

How is Milk Fat Made in the Mammary Gland?
Kevin J. Harvatine, The Pennsylvania State University

Milk fat is a main contributor to the value of milk, and milk fat markets have increased with increasing demand for milk solids and butter. Fat is also the most variable of milk’s components and provides the greatest opportunity to increase farm income. Milk fat is variable within and between farms and is modified by genetics, season of the year, and physiological state that are important for setting goals for milk fat yield. Milk fat is especially responsive to diet and nutrient absorption.

Historically, research has focused on diet-induced milk fat depression (MFD), which is characterized by a reduction of up to 50% in milk fat synthesis that occurs when feeding highly
fermentable and high unsaturated fat diets. Extensive work over the past 20 years has demonstrated that diet induced MFD is caused by unique bioactive fatty acids originating during rumen biohydrogenation of unsaturated FA. Investigation of biohydrogenation-induced MFD has provided mechanistic insight into the regulation of milk fat synthesis. Milk fat depression decreases concentration of de novo synthesized fatty acids (FA) in milk, but other factors such as increasing absorbed fat will also decrease de novo FA. Trans-10 intermediates in milk are a specific marker of BH-induced MFD and odd and branch chain fatty acids may also be used as biomarkers in the future.

Other factors such as fat supplements, acetate supply, and insulin signaling also impact milk fat and result in smaller increases and decreases. Fatty acids specifically differ in their effects on milk fat. Acetate is the main substrate for milk fat synthesis and, although acetate deficiency does not cause milk fat depression, supplementation has been shown to increase milk fat above normal levels. Short and medium chain fatty acids, including palmitic acid, increase milk fat more than long-chain fatty acids. Fat supplementation increases preformed fatty acid incorporation into milk fat, but decreases de novo synthesis, limiting the extent of the increase. The effect of palmitic acid on de novo synthesis will be specifically discussed.

Maximizing milk fat requires minimizing diet-induced milk fat depression, that is specifically responsive to rumen available unsaturated fatty acids and optimizing fat supplements to maximize preformed fatty acid incorporation into milk while minimizing inhibition of de novo synthesis.

Kevin J. Harvatine is an Associate Professor of Nutritional Physiology at Penn State University. He grew up on a dairy farm in Pennsylvania and received his BS in Animal Science from Penn State. His conducted his MS work at Michigan State University working with Dr. Mike Allen and PhD and postdoc work at Cornell University working with Dr. Dale Bauman and Dr. Yves Boisclair. His area of expertise is nutritional regulation of metabolism. Currently he investigates regulation of milk fat synthesis, omega-3 fatty acid metabolism, and circadian regulation of lactation. His lab conducts experiments ranging from applied dairy nutrition to mechanistic molecular biology experiments.

Effects of Fatty Acids on Liver and Adipose Metabolism

Johan Osorio, South Dakota State University, Massimo Bionaz, Oregon State University and Juan Loor, University of Illinois

Use of supplemental fats and oils in diets of dairy cows is a common practice to increase the energy density of such diets. Dietary fats reaching the duodenum will be packed into micelles and absorbed by enterocytes in the small intestine. In the enterocyte, fatty acids (FA) will need to be esterified and packed into chylomicrons or very-low density lipoproteins (VLDL), which are types of lipoproteins that deliver dietary FA to peripheral tissues and remnants FA to the liver. Once lipoproteins reach the peripheral tissues, the final delivery dietary FA to these tissues will rely on the activity of lipoprotein lipase, an enzyme in charge to catalyze TG hydrolysis and, thus, FA absorption in peripheral tissues. The dietary FA remnants from chylomicrons and VLDL will be eventually absorbed by the liver, where they will be either used for energy via β-oxidation or esterified into TG and either accumulated in the liver or re-packed into VLDL for
redistribution in peripheral tissues including the mammary gland. The final fate of dietary FA reaching the adipose and liver will greatly depend on the physiological state of the cow. Around parturition, cows enter a common state of negative energy balance, where the total intake of energy does not meet the energy requirements. Therefore, this is commonly associated with a lipolytic state in the adipose tissue which results in the mobilization of NEFA in an attempt to make up the deficit between energy intake and requirements. As the concentration of NEFA in blood increases around calving or in early lactation, more NEFA are taken up by the liver. Then, NEFA can be oxidized to provide energy, partially oxidized to produce ketone bodies, or esterified into TG either for deliver into blood as VLDL or stored as cytosolic lipid droplets. Because ruminants have inherently low capacity for VLDL secretion while having an efficient mechanism for NEFA esterification in the liver, this scenario can lead to conditions such as fatty liver and ketosis. Other major drivers that regulate these adaptations in peripartal dairy cows are insulin and growth hormone (GH). Hypoinsulinemia promotes gluconeogenesis and suppress the negative feedback of IGF-I to GH, then, high GH concentrations not only stimulate milk production but also enhance and sustain gluconeogenesis in liver and lipolysis in adipose tissue. The knowledge on these metabolic adaptations has been enriched by the use of “omics” technologies providing evidence that these metabolic adaptations rely partially on transcriptional control of gene networks. From a nutritional perspective is the potential to activate the peroxisome proliferator-activated receptors (PPARs), which are transcription factors that have been associated with the coordinated regulation of gene networks related to insulin sensitivity in adipose and FA oxidation in liver during the postpartal period of dairy cows. Such activation of PPARs through dietary FA has been mainly associated with long-chain FA (LCFA). Therefore, it is conceivable that this molecular mechanism might partially explain some of the beneficial effects observed when peripartal cows have been fed or abomasally infused LCFA.

Johan Osorio is an Assistant Professor in the Dairy and Food Science Department at South Dakota State University. He completed his BS at Zamorano University in Honduras and his MS and PhD at the University of Illinois, where he studied nutrition and physiology of peripartal dairy cows and neonatal calves from a molecular biology perspective. At South Dakota State University, Osorio continues his efforts to expand the understanding of how nutrients interact with the genome of dairy cows with the aim to explain responses in performance and causal factors of metabolic disorders.

Effect of Fatty Acids on Reproduction in Dairy Cows
José E.P. Santos, University of Florida

Dairy cows are fed diets with moderate content of long chain fatty acids (LCFA). In most diets, LCFA represent 4 to 5% of the total DM and 12 to 16% of the net energy for lactation consumed by dairy cows. One of the effects of supplementing diets of dairy cows with LCFA is a potential improvement in reproduction. Addition of LCFA to diets fed to dairy cows starting in the transition period resulted in 27% increase in the relative risk of pregnancy to an insemination. Numerous potential mechanisms have been described by which fat supplementation might influence reproduction. Fatty acids impact follicle development, luteal secretion of progesterone, endometrial function, embryo quality, and conceptus elongation. The effects of feeding fat seem to be irrespective of caloric provision because supplemental fatty acids in early lactation do not
improve energy balance or reduce losses of body condition. In fact, the beneficial effects of LCFA on reproduction are likely related to the type of fatty acid absorbed. The polyunsaturated FA of the n-6 and n-3 families seem to have the most biological effects on reproduction in cattle. These FA or products of their cellular metabolism can act through nuclear receptors such as PPAR-gamma and influence elongation of the conceptus. Furthermore, n-3 fatty acids likely alter T-lymphocyte lineage in reproductive tissues resulting in more immune-tolerant phenotypes that favor maintenance of pregnancy.

**José E.P. Santos** is a Research Foundation Professor in the Department of Animal Sciences at the University of Florida where he conducts research and extension in dairy cattle nutrition and reproduction. José earned his DVM degree from São Paulo State University in Brazil in 1992, completed the MSc and PhD degrees in 1995 and 1997 at the University of Arizona, and a clinical residency in Dairy Production Medicine in 2000 in the School of Veterinary Medicine at the University of California Davis. He spent 8 years as a faculty member with clinical and research responsibilities in the Department of Population Health and Reproduction in the School of Veterinary Medicine at the University of California Davis before moving to the University of Florida in 2008. In 2017, he did a sabbatical at Scibus Australia and in the School of Veterinary Sciences at the University of Sydney. José has been the major professor of 31 graduate students, co-major professor of 7 visiting PhD students, he has hosted 10 sabbatical visitors and post-doctorates, and his laboratory has hosted more than 100 visiting students. José has published 205 peer-reviewed manuscripts in the scientific literature, 14 book chapters, and numerous abstracts and technical articles/presentations in the area of animal nutrition and reproduction. He has received over $10 million in research funding to support his program as principal or co-principal investigator. His primary research efforts focus on the interface between nutrition and reproduction and methods to improve postpartum health and fertility of dairy cows.

**Nutrient Partitioning and the Role of Fatty Acids in the Dairy Cow**

*Joseph McFadden, Cornell University*

The partitioning of nutrients to support milk production in the early lactation dairy cow involves a coordinated series of endocrine and biochemical events. A decrease in skeletal muscle and adipose tissue insulin sensitivity and responsiveness, and low circulating insulin and insulin-like growth factor-1 concentrations spare glucose for the mammary synthesis of milk. In addition, somatotropin and catecholamines help promote adipose tissue lipolysis to provide fatty acids for oxidative metabolism, ketogenesis, and milk fat production. The role of adipokines (e.g., adiponectin) and hepatokines (e.g., fibroblast growth factor-21) is less certain. Identifying bioactive nutrients capable of modulating nutrient partitioning and insulin signaling has implications for improving health, milk production efficiency, and longevity in dairy cattle. Fatty acids have received attention for their ability to modify insulin action. Saturated palmitic acid can provoke insulin resistance and suppress glucose-stimulated insulin secretion in non-ruminant models of type 2 diabetes and non-alcoholic fatty liver disease. The mechanisms involve mitochondrial dysfunction, inflammation, and the synthesis of the insulin antagonist ceramide. On the other hand, omega-3 fatty acids including docosahexaenoic acid appear to elicit insulin-
sensitizing and health-promoting properties. In the cow, glucose utilization, lipolysis, immunity, hepatic health, and milk production may be influenced by fatty acid nutrition. However, our understanding of how specific fatty acids influence these outcomes is unclear and complicated by the biohydrogenation of unsaturated fat, differences in fatty acid digestibility, changes in physiology across lactation, production level, parity, body condition status, and the confounded involvement of lipolytic fatty acids. Nevertheless, recent work has explored the role of fatty acids on metabolism and milk production in cows. For example, palmitic acid feeding enhances ceramide synthesis, relative to no-added fat, stearic acid, or medium-chain triglycerides. This effect may explain why dietary palm fat supplementation has been shown to reduce glucose-stimulated reductions in circulating total fatty acid concentrations, and increase energy partitioning toward milk production, relative to no-added or unsaturated fat feeding, respectively. To target C22:0-ceramide, which is associated with reduced insulin sensitivity in dairy cattle, we demonstrated that cows abomasally infused behenic acid (C22:0) have higher plasma ceramide concentrations, relative to those infused palmitic acid. In this study, milk production was equivalent even though the digestibility of behenic acid is expected to be far lower than palmitic acid. Reductions in insulin sensitivity by ceramide may explain this finding. The delivery of unsaturated palmitoleic acid in the diet to lambs or docosahexaenoic acid via abomasal infusion to late lactation cows appears to keep ceramide levels low, relative to unsupplemented or palm fat-infused animals, which supports work demonstrating the ability of these fatty acids to enhance insulin sensitivity. This could be of importance to the transition cow that experiences lipolysis and depletion of polyunsaturated fatty acids. In conclusion, evidence suggests that fatty acids uniquely influence nutrient partitioning in dairy cattle. Fatty acid feeding strategies that exploit these mechanisms at the appropriate stage of lactation may be a means to control glucose utilization, lipolysis, hepatic triglyceride deposition, and milk production.

**Joseph McFadden** is an assistant professor and Northeast Agribusiness and Feed Alliance Faculty Fellow in Dairy Cattle Biology in the Department of Animal Science at Cornell University. He received a B.S. in Animal Science with Distinction in Research from Cornell University, an M.S. in Animal Science from the University of Illinois, and a Ph.D. in Dairy Science from Virginia Tech. After a postdoctoral fellowship in the Department of Neuroscience and the Center for Metabolism and Obesity Research at Johns Hopkins Medicine, McFadden joined the biochemistry faculty at West Virginia University in 2012. He moved his lab to Cornell in 2017. His federal and industry supported research goals are to develop next generation nutritional therapies to improve hepatic and intestinal health, heat stress resilience, and milk production efficiency in dairy cattle. In the classroom, he teaches nutritional physiology and biochemistry. He also currently mentors five PhD students and two postdocs.

**Friday May 31, 2019**

**Important Aspects of Milk Fat Relating to Processing and Product Quality**

*Lloyd Metzger, South Dakota State University*

Milk fat consist of a variety of mixed triglycerides that includes 20 different fatty acids present at high levels and more than 250 that are present at low levels. Milk fat contains 47-68%
saturated fat acids, 27-41% monounsaturated fatty acids and 2.7-4.2% polyunsaturated fatty acids. The fatty acid type and position in the triglyceride impact the melting point and hardness of milkfat. In its native form, milk fat exists in milk fat globules that are dispersed in the water phase of milk. They range in size from .2 to 15 microns in diameter. They are surrounded by a layer called the milk fat globule membranes that consists of mono and diglycerides, phospholipids, sterols, lipoproteins and enzymes. The milk fat globule can be separated from the serum phase of milk using mechanical separation to produce cream with various fat contents. If milk is homogenized the original fat globule membrane is ruptured and replaced with casein, whey protein and phospholipids. Homogenization also results in a reduction of the fat globule size to < 1 micron.

During the manufacture of products like whipped cream and butter the native milk fat globule membrane is ruptured when crystalline fat is present. This leads to aggregation and coalesce of the fat globules. A major factor influencing the hardness and spreadability of butter is the melting point of milk fat. As mentioned previously the melting point of milk fat is determined by the type and position of fatty acids in the triglyceride. Numerous feeding practices such as grass-based diets, flax seed/camelina, or dietary calcium soaps have an impact on the unsaturated fat content and spreadability of butter produced from the milk fat.

The minor components present in the milk fat globule membrane including mono and diglycerides, phospholipids, lipoproteins and enzymes can have a major impact of the flavor and functionality of products produced from milk. From a flavor perspective oxidized off-flavors are a major factor in the shelf life of fluid milk and are one of the most common flavor defects. The presence of oxidized off-flavors are influenced by numerous factors including cow health, dietary factors, and processing and handling of milk. Recently a rapid test for measuring the oxidative stability of milk was developed and can be used to identify factors that are impact development of oxidized off-flavors. From a functionality perspective these minor components have a major impact on the foam stability of products. This is a major issue in cappuccino style beverages where skim milk is used to produce a foam during the heating process. If the milk used to produce these beverages contains elevated levels of phospholipids, free fatty acids, or mono and diglycerides the foam formed will rapidly collapse and produce a low-quality foam.

Lloyd Metzger is a Professor and Alfred Chair in Dairy Education at South Dakota State University. He is the Director of the Midwest Dairy Foods Research Center and the Institute for Dairy Ingredient Processing. He also serves as executive secretary of the North Central Cheese Industry Association. Metzger obtained his Bachelor and Master of Science degrees in Dairy Manufacturing from South Dakota State University and his doctorate in Food Science from Cornell University. Prior to joining South Dakota State University, he was employed as a research scientist at General Mills and as an Assistant and Associative Professor in the Food Science and Nutrition department at the University of Minnesota-St. Paul.

Mid-Infrared (MIR) Analysis of Milk Fatty Acid Concentration and FA Profile for Dairy Cattle Management
Dave Barbano, Cornell University
Mid-infrared (MIR) milk analysis has been the method choice for rapid milk analysis for both milk payment testing and dairy management record keeping since the mid 1980’s. Over the years the MIR instrument technology has evolved from the use of simple optical filters to the current Fourier MIR spectrophotometers that can collect a complete spectral fingerprint of a milk in a fraction of second. The challenge has been to analyze and interpret the subtle detail of the MIR fingerprint of milk and to relate that information to the nutrition and metabolic status of the dairy cow to provide timely and actionable information for farm feeding and health management decision making. Current research is leading the dairy industry down that path. The management structure, automation and scale of dairy farm milk production has been changing rapidly and offers opportunities for better integration of both information from milk analysis technology for new directions in milk analysis using sensors. When combined with other on-farm sensing technologies (e.g., activity monitors) real time information for management decision will become a reality.

An example of this change is the new farm management MIR milk analysis metrics for relating changes in the proportions of different groups of fatty acids (de novo, mixed origin, and preformed fatty acids expressed in grams/100 grams milk) and mean fatty acid chain length (carbon number) and unsaturation (double bonds per fatty acid) in milk to bulk tank fat and protein concentration to changes in dairy cattle ration composition and quality. Recent data has shown a strong correlation of milk fatty acid composition with seasonal variation of fat and protein in dairy herds in the US. In addition, a new metric to estimate blood nonesterified fatty acids (NEFA) from the milk provides a rapid and cost-effective tool to determine metabolic status of early lactation cows without taking a blood sample. The goal is to reduce the incidence of ketosis and displaced abomasum in early lactation. Currently representative milk samples are collected and analyzed with an instrument in a laboratory, but in the future development of real time sensor technology for this type of milk analysis would be of great value for both feeding and health management of dairy cows on large farms.

The first application of the new farm management milk testing metrics has been at the bulk tank level using the same milk analysis instrument and samples collected and used for milk payment testing. The incremental cost of implementation of this technology is low and the turn-around time of data back to the dairy farmer is typically within 36 hours of milk collection on milk payment samples. This is now being used in at least 10 milk testing (payment/DHIA) laboratories in the US. On large farms, dairy nutritionists are working with companies that produce automated milk sampling devices to obtain milk samples from feeding groups of cows on large farms to relative milk fatty acid composition to how effectively the cows are converting feed to high value components in milk. Ultimately, this impacts the financial performance of milk production. There is a large and systematic change in milk fatty acid composition with stage of lactation. As dairy farms get larger and groups of cows at similar stage of lactation are milked as a group, it may be feasible for a large dairy farm to supply and sell added value tanker loads of milk with different milk fatty acid composition targeted for specific dairy product applications.

Dave Barbano is a Professor of Food Science at Cornell University and Director for Northeast Dairy Foods Research Center. Dave received both his MS and PhD from Cornell University. Dave conducts an applied and basic research program on dairy product manufacturing with a focus on cheese manufacturing and chemistry. He also does research on milk analysis for dairy herd management. Recently, Dave has focused on developing new measures of cow metabolic
health, nutrient utilization, and metabolic stress for dairy herd management using mid-infrared milk analysis. He has been very active in the analytical groups of International Dairy Federation and the Association of Official Analytical Chemists International for the past 30 years. He has been a member of the American Dairy Science Association since 1974 and is a past president of ADSA.

**JDS Reprint: A 100-Year Review: Fat Feeding of Dairy Cows**

Donald L. Palmquist, The Ohio State University

Over 100 years, the *Journal of Dairy Science* has recorded incredible changes in the utilization of fat for dairy cattle. Fat has progressed from nothing more than a contaminant in some protein supplements to a valuable high-energy substitute for cereal grains, a valuable energy source in its own right, and a modifier of cellular metabolism that is under active investigation in the 21st century. Milestones in the use of fats for dairy cattle from 1917 to 2017 result from the combined efforts of noted scientists and industry personnel worldwide, with much of the research published in *Journal of Dairy Science*. We are humbled to have been asked to contribute to this historical collection of significant developments in fat research over the past 100 years. Our goal is not to detail all the work published as each development moved forward; rather, it is to point out when publication marked a significant change in thinking regarding use of fat supplements. This approach forced omission of critically important names and publications in many journals as ideas moved forward. However, we hope that a description of the major changes in fat feeding during the past 100 years will stimulate reflection on progress in fat research and encourage further perusal of details of significant events.

**Key words:** fat, conjugated linoleic acid, energy, 100-year review

Donald L. Palmquist received a B.S. degree in Dairy Production from Oregon State College and a PhD in Nutrition from the University of California, Davis. After 2 years of post-doctoral studies in Dairy Metabolism at the University of Illinois, he joined the Department of Dairy Science at The Ohio Agricultural Research and Development Center/The Ohio State University, Wooster in 1967. In early research at OARDC, kinetic analysis of radio-labeled palmitic acid transfer from diet or blood to milk fat was used to establish the importance of dietary fat in the synthesis of milk fat. The limitations of using “ether extract” to estimate fat utilization and metabolism was recognized and led to development of a method that measured fatty acids quickly and precisely; now used widely in research (cited more than 2000 times). This led to extensive studies on developing fat feeding systems for high-producing cows. Concepts of using fat to maximize forage intake and stabilize rumen function were pioneered and are now firmly established. The interaction of calcium with fat in the rumen was studied in detail, which led to development of a new feed fat, calcium soap. The concept was patented by OSU and the product is accepted worldwide as the leading fat supplement in diets of high producing dairy cattle. Physiological studies quantified lipoprotein turnover and uptake of diet-derived and endogenous lipoproteins by mammary gland in lactating cows; this information, together with fat digestibility studies, led to development of a physiological basis for requirements of dietary fat by lactating cows. More recent research focused on relationships between the cow’s diet and milk fat composition and quality. Endogenous synthesis of CLA in rodents, ruminants and
humans was quantified. We have published the only quantitative synthesis of CLA from vaccenic acid in humans. Peer publications were 99, with 495 total publications and presentations, and 2 patents. Awards and honors included The American Cyanamid award (1989), AFIA Nutrition award (1992), ADSA Fellow (2003), FASS AFIA Frontiers in Animal Nutrition (2008) and ADSA Distinguished Service (2014). He has trained ten MS and 6 PhD students; also 4 Post-Doctoral and 13 visiting scientists worked in his lab. He taught a PhD-level course in Lipid Nutrition and Metabolism and graduate-level courses in Ruminant Nutrition, Physiology and Metabolism.

White Paper/Bullet Points Relating to Milk, Saturated Fat and Human Health

Dale E. Bauman, Cornell University
Adam L. Lock, Michigan State University

Dale E. Bauman is Liberty Hyde Bailey Professor Emeritus at Cornell University. Raised on a Michigan dairy farm, he received his undergraduate and graduate degrees at Michigan State University and the University of Illinois. Bauman's research focus has included the lactation biology, regulation of metabolism and nutrient partitioning, and environmental impact of animal production. Recently named as one of the “World’s Most Influential Scientific Minds”, he has coauthored more than 800 scientific articles. Bauman has received awards from several scientific and professional societies, Fellow for ADSA, ASAS and ASN, as well as the USDA Distinguished Service Award and the Alexander Von Humboldt Award for Ag Research. Elected to the National Academy of Sciences, Bauman has served on several USDA Advisory Committees, President of American Society for Nutrition and Chairman of the National Academy of Sciences Board on Agriculture & Natural Resources.